Novel Processing Approaches to Enable EUV Lithography toward High Volume Manufacturing

Cecilia Montgomery[1], Jun Sung Chun[1,2], Yu-Jen Fan[1], Shih-Hui Jen[1], Mark Neisser[1], Kevin Cummings[1], Takashi Saito[3], Lior Huli[3], David Hetzer[3], Hiroie Matsumoto[3], Andrew Metz[3], and Vinayak Rastogi[3]

[1]SEMATECH, [2]SUNY Polytechnic Institute, [3]TEL Technology Center, America, LLC, Albany, NY, USA 12203

Instructions

Cycles of Learning

- Line and Space
  - 11 resists were exposed in BMET in 2014.
  - 2 data points are included from Nanoparticle resists
- Contact Hole
  - 13 resists were exposed in BMET in 2014.
  - 3 of best resists from entire cycle of learning until now were carried out for LCDU improvement project combined with Tokyo Electron Limited (TEL).

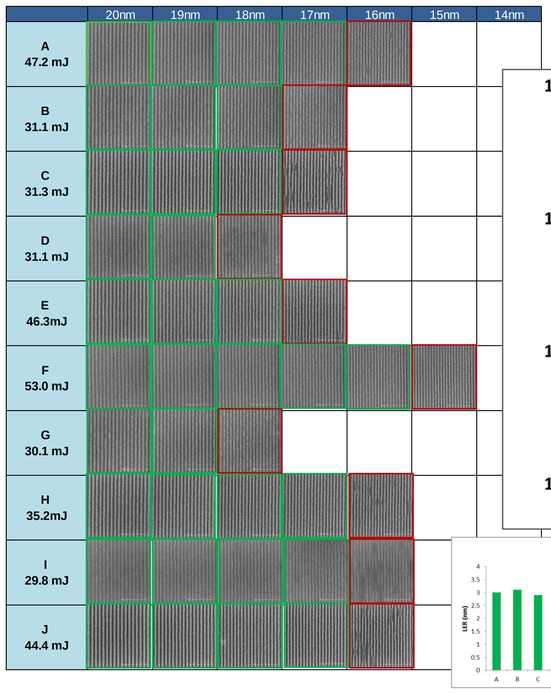
Process optimization incorporating coater/developer and etching techniques

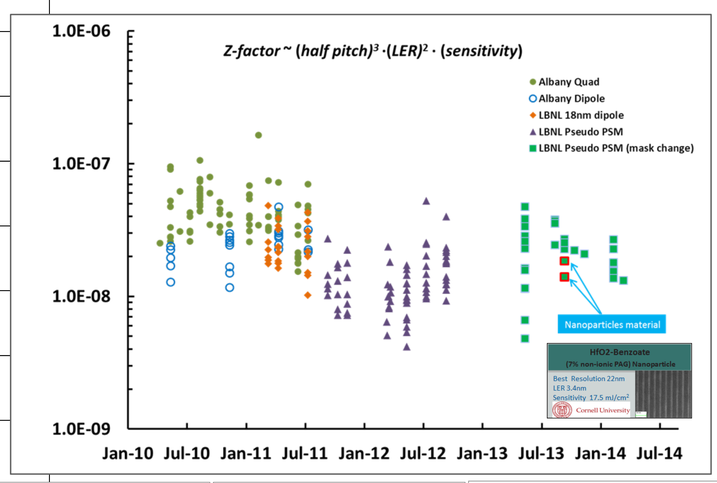
- LCDU improvement
  - Evaluate C/H resists from SEMATECH Cycle of Learning and choose best for LCDU
  - Show the first result of implementation for LCDU improvement by coater/developer process.
- HSEUV (High Speed EUV) process
  - Show initial result using novel patterning concept with EUV for comparison relative to conventional method.

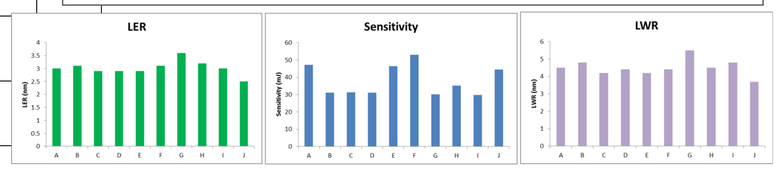
Cycles of Learning (COL)

EUV Line and Space Resist Performance

SEMATECH Berkeley MET PSM, NA 0.3
FT 60nm , data was measured at ≤20nm hp
Best resolution L/S resist from each vendor

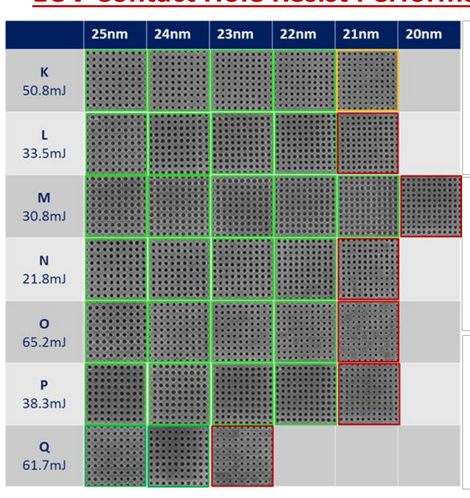


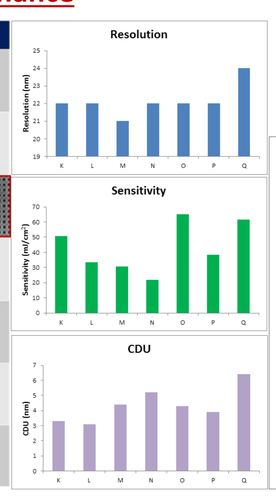




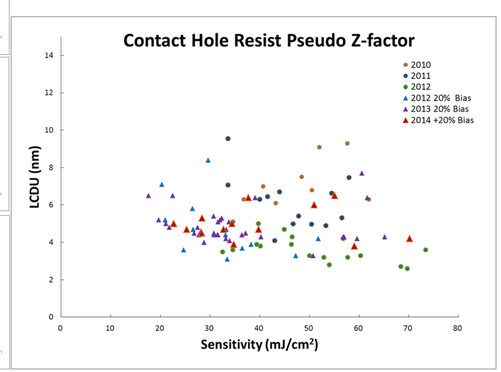
Summary for 2014 L/S Resist Cycle of learning
- EUV CAR resist evaluated in 2014 shows no significant improvement.
- The first look at Nanoparticle Resist show promising results as compared to CAR

EUV Contact Hole Resist Performance





SEMATECH Berkeley MET Quad, NA 0.3
FT 60nm , mask +20% Bias
CDU was measured at 26nm hp
Best resolution C/H resist from each vendor



Summary for 2014 C/H Cycle of learning
- No significant improvements in 2014 on the performance of EUV Chemically Amplified Resist .

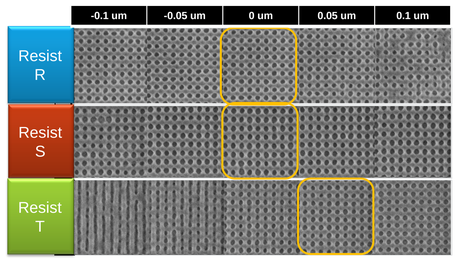
Process optimization incorporating coater/developer and etching techniques

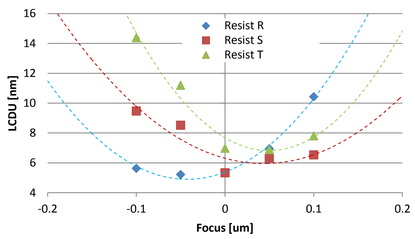
LCDU improvement

C/H Resist Screening

- **Measurement scheme**
  - Take 4 images per shots
  - Measure 20 holes per images
  - Estimate LCDU / CER

➢Resist : 3 resists
➢Inspection : S9380 (Hitachi HT)
➢Samples : FEM from Albany MET
➢Target CD : 28 nm 1:1

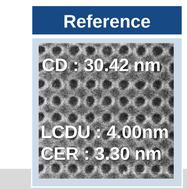


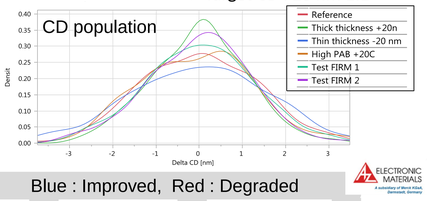


Litho Optimization

- **Measurement scheme**
  - Take 20 images per shots
  - Measure 20 holes per images
  - Estimate LCDU / CER

➢Inspection : CG4100 (Hitachi HT)
➢Samples : FEM from Albany MET
➢Resist : Resist R
➢Target CD : 28 nm 1:1





Blue : Improved, Red : Degraded

Thick thickness + 20 nm	Thin thickness – 20 nm	Low PAB – 20 degC	High PAB + 20 degC	FIRM Test sample 1	FIRM Test sample 2
LCDU : 16 % CER : 20 %	LCDU : - 19 % CER : - 7 %	Bad resolution	LCDU : -3 % CER : 13 %	LCDU : 4 % CER : 14 %	LCDU : 11 % CER : 22 %
CD : 30.26 nm LCDU : 3.36nm CER : 2.65 nm	CD : 29.52nm LCDU : 4.75nm CER : 3.53 nm	CD : N/A LCDU : N/A CER : N/A	CD : 29.77nm LCDU : 4.12nm CER : 2.86 nm	CD : 29.55nm LCDU : 3.83nm CER : 2.85 nm	CD : 28.30nm LCDU : 3.58nm CER : 2.59 nm

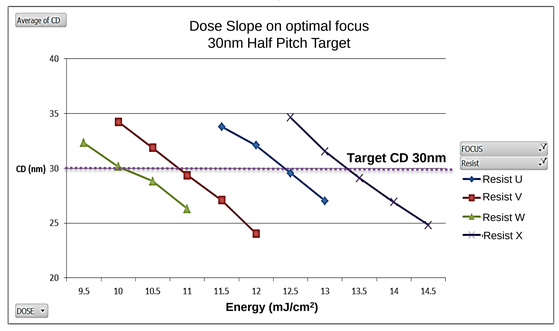
Etching Optimization

	Optimal etching recipe
Post litho (Ref)	CD : 33.75 nm LCDU : 5.02nm CER : 3.72 nm
OPL open	CD : 23.99 nm LCDU : 2.15nm CER : 1.93 nm
Ox / SiN HM open	CD : 23.83 nm LCDU : 1.91nm CER : 1.76 nm

HSEUV (High Speed EUV) process

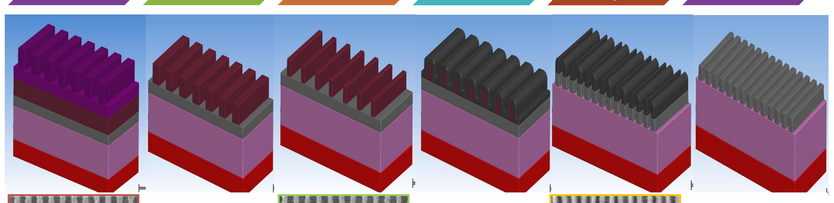
Resist Screening for "High Speed Resists"

Resist U	Resist V	Resist W	Resist X
12.5 mJ/sqcm	11.0 mJ/sqcm	10.0 mJ/sqcm	13.5 mJ/sqcm



Proposed Process Scheme

Post litho 30nm hp → OPL mask open → OPL mask trimming → ALD spacer depo → OPL core HM/Spacer open → Final CD 15nm hp

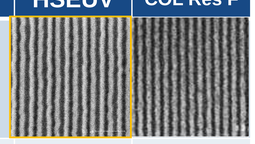


Post Litho
CD : 29.7 nm
LWR : 7.5 nm
LER : 5.5 nm

Post OPL trim
CD : 22.4 nm
LWR : 6.0 nm
LER : 5.5 nm

Post OPL core open
CD : 16.2 nm
LWR : 5.8 nm
LER : 5.4 nm

Comparison of Processes

	HSEUV	COL Res F
Top down @15 nm		
Sensitivity [mJ/sqcm]	10.0	53.0
LER [nm]	5.4	4.8
* Estimated Thru-put	93 wph	30 wph

* The estimated thru-put is based on 85 W source power

Summary

- Summary for 2014 L/S Resist Cycle of learning
  - EUV Chemically Amplified Resist evaluated in 2014 shows no significant improvement.
  - The first look at Nanoparticle Resist show promising results as compared to CAR.
- Summary for 2014 C/H Cycle of learning
  - No significant improvement in 2014 for the performance of EUV Chemically Amplified Resist
- In progress Litho / Etch optimization for LCDU improvement
  - Thicker resist and FIRM process showed improvement of LCDU/CER up to 15-22% at post Litho
  - Demonstrated Oxide/ SiN open with optimal etch recipe; Shows 1.91 nm LCDU, 1.76 CER post the HM open
- Demonstrated HSEUV concept with high sensitivity resist
  - Estimated thru-put with 85W source power for HSEUV flow is >90 wph compare to 30 wph for original process flow
  - Although it is a double patterning technology, the proposed process still only requires a single pass through the EUV tool